

FETC Conference
2000 Conference on Selective Catalytic-
Selective Non Catalytic Reduction for NO_x Control
Greentree Radisson, Pittsburgh, PA
May 17-18, 2000

The Case for Low Ammonia Slip

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Summary

The trouble- and maintenance-free operation of a retrofit or newly constructed Selective Catalytic Reduction (SCR) system is, to a large extent, determined by the amount of unreacted ammonia that leaves the SCR reactor. A proper compromise of NO_x reduction efficiency, choice of operating temperature, size of the reactor, choice of catalyst, and design of downstream equipment for easy maintenance is the key to reliable operation without unscheduled outages. The case for low slip ammonia is made in this paper based on field experience and the fundamentals of the ammonia-sulfur chemistry.

Background

There is now over 20 years of operating experience with Selective Catalytic Reduction (SCR) technology on coal-fired boilers. For sulfur-containing fossil fuels, the most important design challenge is to minimize and manage ammonia bisulfate formation and deposition on heat transfer surfaces downstream of the SCR. Of particular importance is fouling of the air preheater that impacts plant availability, efficiency and maintenance costs.

Each design is a unique interaction of the process parameters that control the chemistry and condensation of ammonium salts. The important parameters that need to be considered are:

- inlet NO_x concentration;
- fuel sulfur content;
- SCR reactor temperature;
- air preheater temperature profile;
- mechanical design of the air preheater; and
- fan capacity.

Several European, Japanese and North American studies and investigations have focused on the air heater design to minimize sulfate deposition. These studies found that in most

instances the sulfate deposition can be successfully managed when the ammonia slip is 2 ppm and less. However, some units have inoperable air heater back pressure and excessive fouling even with these low levels of ammonia slip. This analysis focuses on the differences between the units and makes the case for evaluating individual systems on a case-by-case basis to determine the ammonia slip limits required to ensure reliable operation. An assessment of options and guidelines for a unit faced with inoperable fouling problems is also covered in this analysis.

Salt Formation

Sulfate salts are formed in quantities that are in proportion to the gaseous SO_3 in the combustion gases. SO_3 is formed by oxidation of SO_2 in the burners during combustion of the fuel, thermodynamically limited to a few percent at high temperature. Further SO_3 formation occurs by reaction of SO_2 with oxygen over the SCR catalyst.

SO_3 reacts with unreacted ammonia from the SCR reactor and condenses as a solid phase sulfate in the cold sections of the air preheater. There are two predominant sulfates, ammonium sulfate and ammonium bisulfate. The proportions of these two salts are determined by the relative concentrations of slip ammonia and SO_3 . For coal boilers where the SO_3 concentration is always larger than the ammonia concentration, the predominant product is ammonium bisulfate, a yellow, sticky solid. The excess SO_3 condenses as sulfuric acid in the air heater and adds to corrosion and fouling of the APH elements.

What is Acceptable Ammonia Slip?

The design limits for slip ammonia are more important than the NO_x conversion for the reliable operation of the SCR system. For a coal-fired unit, the ammonia slip level also determines the ammonia levels in the fly ash. Fly ash handling and disposal requirements limit the ammonia content that can be tolerated.

Many units operate successfully with ammonia slip design limits of 2 to 5 ppm, commonly recommended for acceptable operation of the APH. While some units designed for 2 ppm ammonia slip operate well, this is because their actual ammonia slip is in the range of 0.5 to 1.5 ppm. Units that operate more closely to the design limit often experience fouling and are forced to take several unscheduled outages a year due to APH fouling. Based on our analysis, 2 ppm ammonia slip is not acceptable in many instances, particularly for the sulfur levels of US coals.

Designing for Low Ammonia Slip

Details of case studies involving air preheater fouling are made in the presentation. A set of design guidelines for reliable operation of the SCR is provided:

1. Selection of an operable NO_x conversion. Systems with a NO_x conversion requirement below 70 to 80% have greater success at operating long-term with minimal APH fouling, because they are less likely to exceed the maximum ammonia slip allowance.
2. Determination of the proper ammonia slip level that matches the system parameters. To minimize fouling, the ID and FD fan capacity, the type and material of construction of the APH elements, the element configuration, the APH temperature profile, and on-line cleaning capability must be taken into account. Examples will be presented.
3. Selection of the appropriate SCR catalyst. The location, operating temperature and catalyst formulation (SO₂ to SO₃ conversion rate).
4. Designing the reactor to allow for sufficient space for future additional catalyst. For retrofits, space is at a premium and often spare capacity is not adequately provided for in the design. This increases the risk of failure and adds to operation costs and unscheduled outages.
5. Consideration of additional levels of ammonia injection. Multiple levels of ammonia injection between catalyst layers offer the best insurance for successful, low maintenance operation.